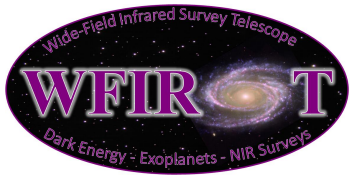


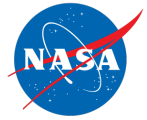


# WFIRST Design Reference Mission Summary & Programmatics

April XX, 2013

Kevin Grady
Cathy Peddie
Mark Melton
Dave Content
Jennifer Dooley
Marie Levine

Draft 3-18-2011

# AFTA-WFIRST Study Charter

- Assess the possible astrophysical use(s) of the optical telescope assets received from the National Reconnaissance Office (NRO) to address the science priorities described in the Astrophysics 2010 Decadal Survey *New Worlds New Horizons* (NWNH) for a wide field infrared survey telescope.
- Develop an optimized WFIRST-AFTA Design Reference Mission (DRM).
- Address complementarity of WFIRST-AFTA DRM science with planned domestic and international ground and space facilities.
- Mission cost is to be kept low while achieving all or part of the science priorities for a wide-field infrared survey telescope.
- Include modularity to facilitate on-orbiting servicing.
- Options to be assessed/studied:
  - Internal coronagraph.
  - GEO orbit to support robotic servicing.
  - Optical communication.

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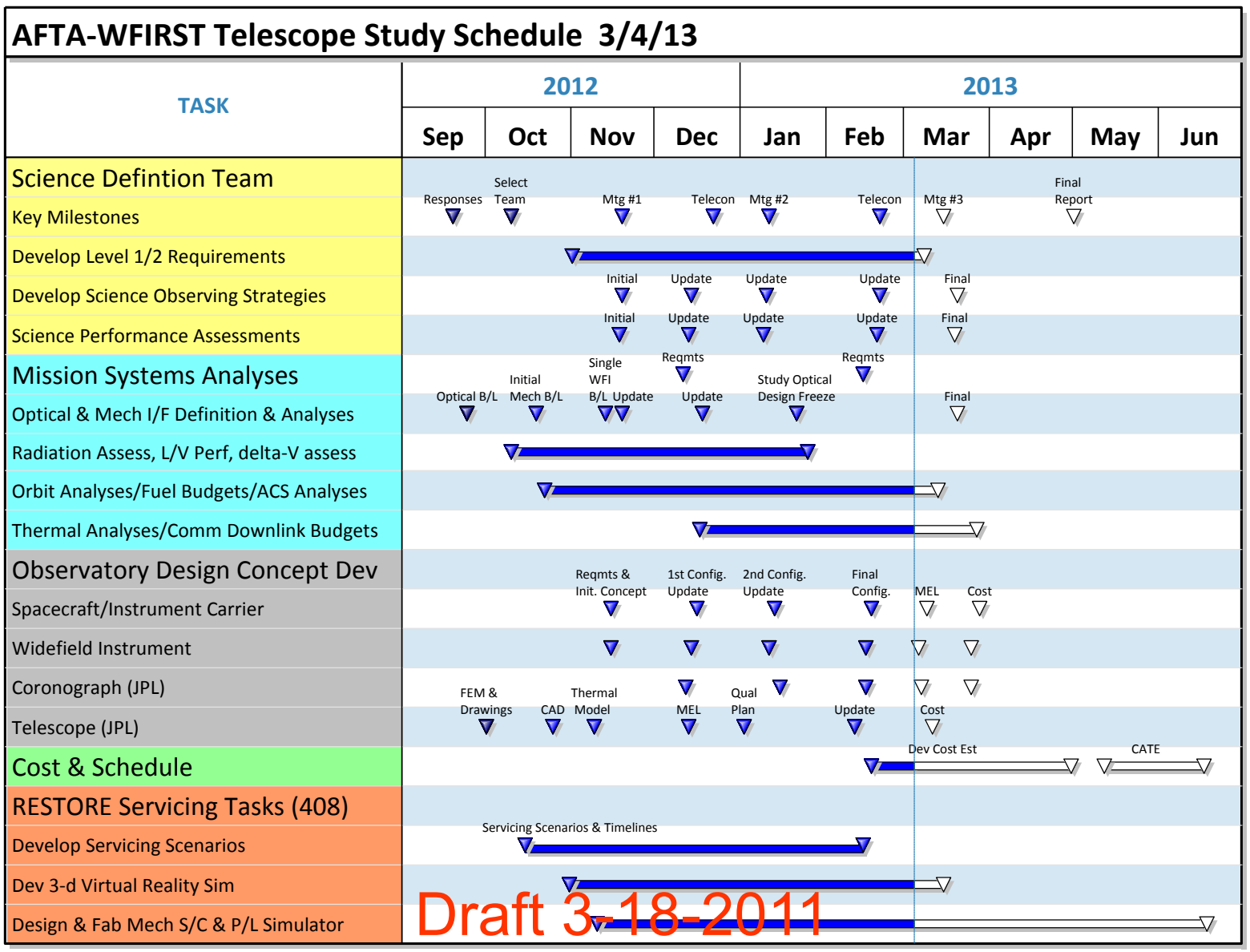
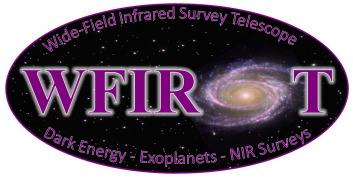
# WFIRST-AFTA Study Schedule






# WFIRST-AFTA Science Objectives


- Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets, including analogs of all of the planets in our Solar System with the mass of Mars or greater.

- Determine the expansion history of the Universe and the growth history of its largest structures in order to test explanations of its apparent accelerating expansion including Dark Energy and modifications to Einstein's gravity.

- Produce a deep map of the sky at NIR wavelengths, enabling new and fundamental discoveries ranging from mapping the Galactic plane to probing the reionization epoch by finding bright quasars at z>10.

- Provide a general observer program utilizing a minimum of 10% of the mission minimum lifetime.

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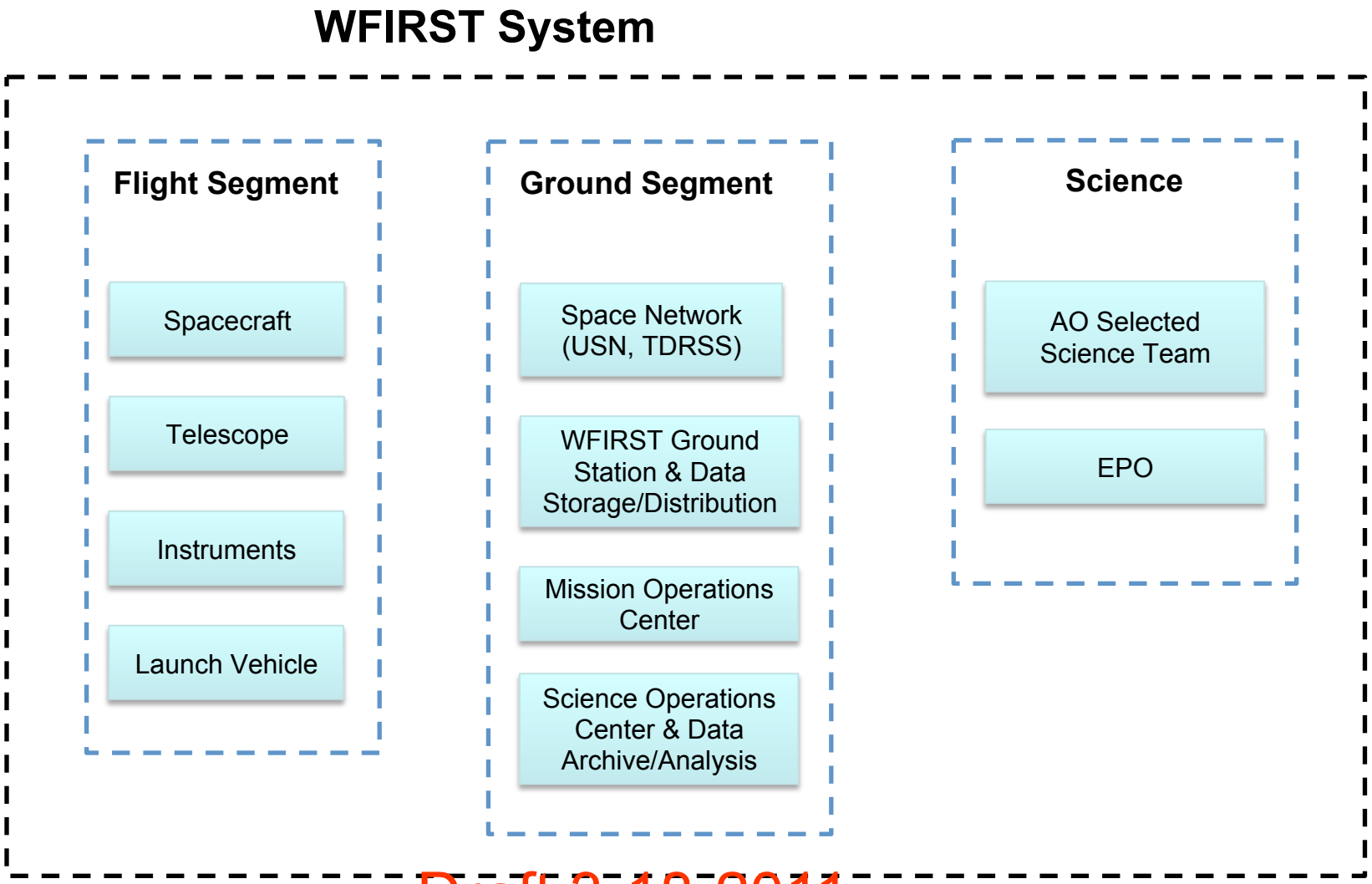
# WFIRST-AFTA Mission Functional Elements

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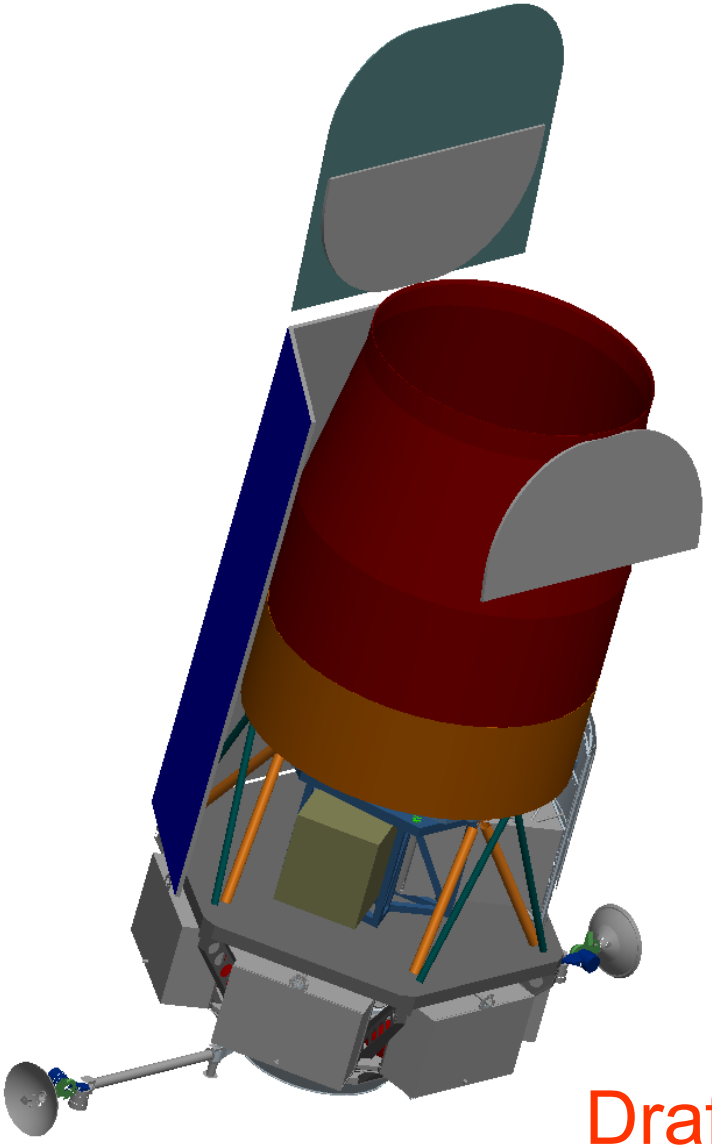
# WFIRST-AFTA Observatory Concept



## Key Features

- Telescope – 2.4m aperture primary
- Instrument – Single channel widefield instrument, 18 HgCdTe detectors; integral field unit spectrometer incorporated in widefield for SNe observing
- Overall Mass – ~6500 kg with components assembled in modules
- Primary Structure - GrEp
- Downlink Rate – Continuous 400 mbps Ka-band to Ground Station
- Thermal – passive radiator
- Power – 2800 W with GaAs solar array
- GN&C – reaction wheels & thruster unloading
- Propulsion – bipropellant
- Launch Vehicle – Atlas 531

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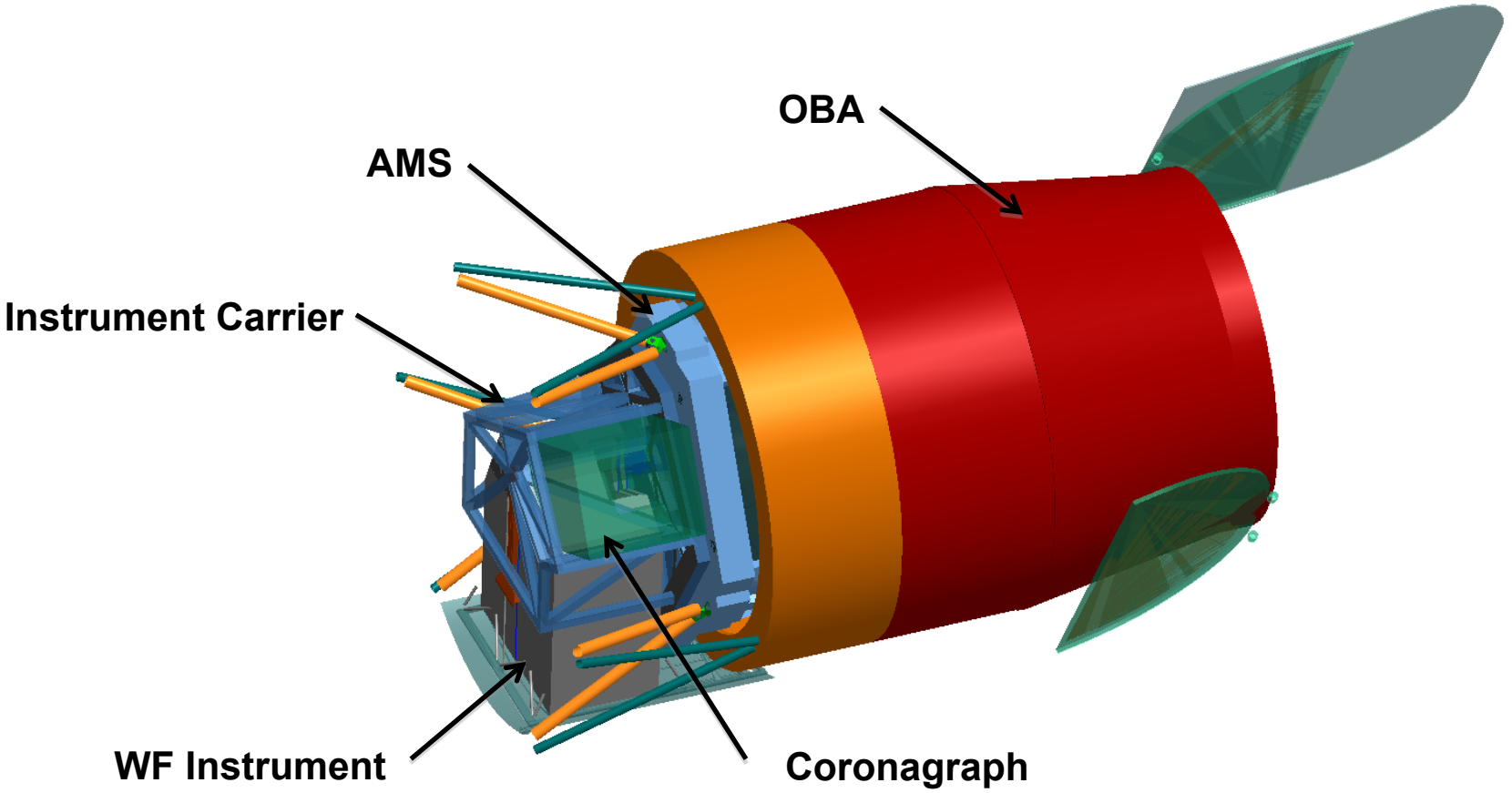
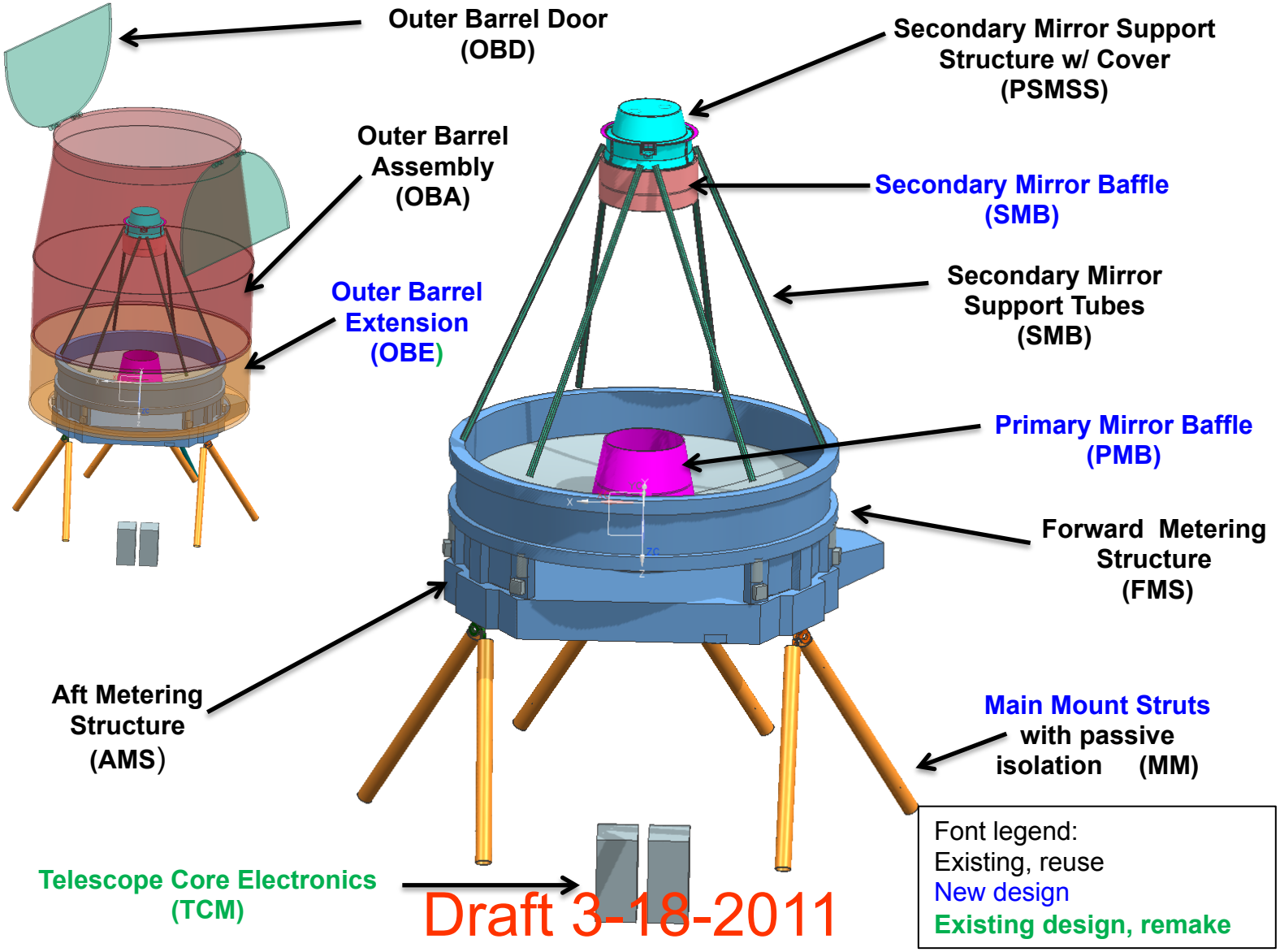
# AFTA-WFIRST Payload Design Concept



# WFIRST-AFTA Telescope

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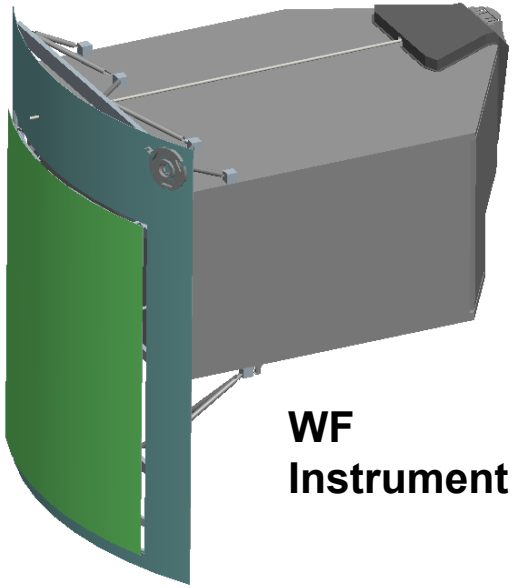
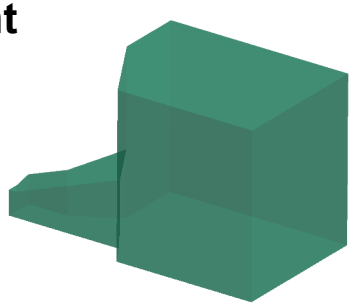
# WFIRST-AFTA Instrument Carrier Design Concept



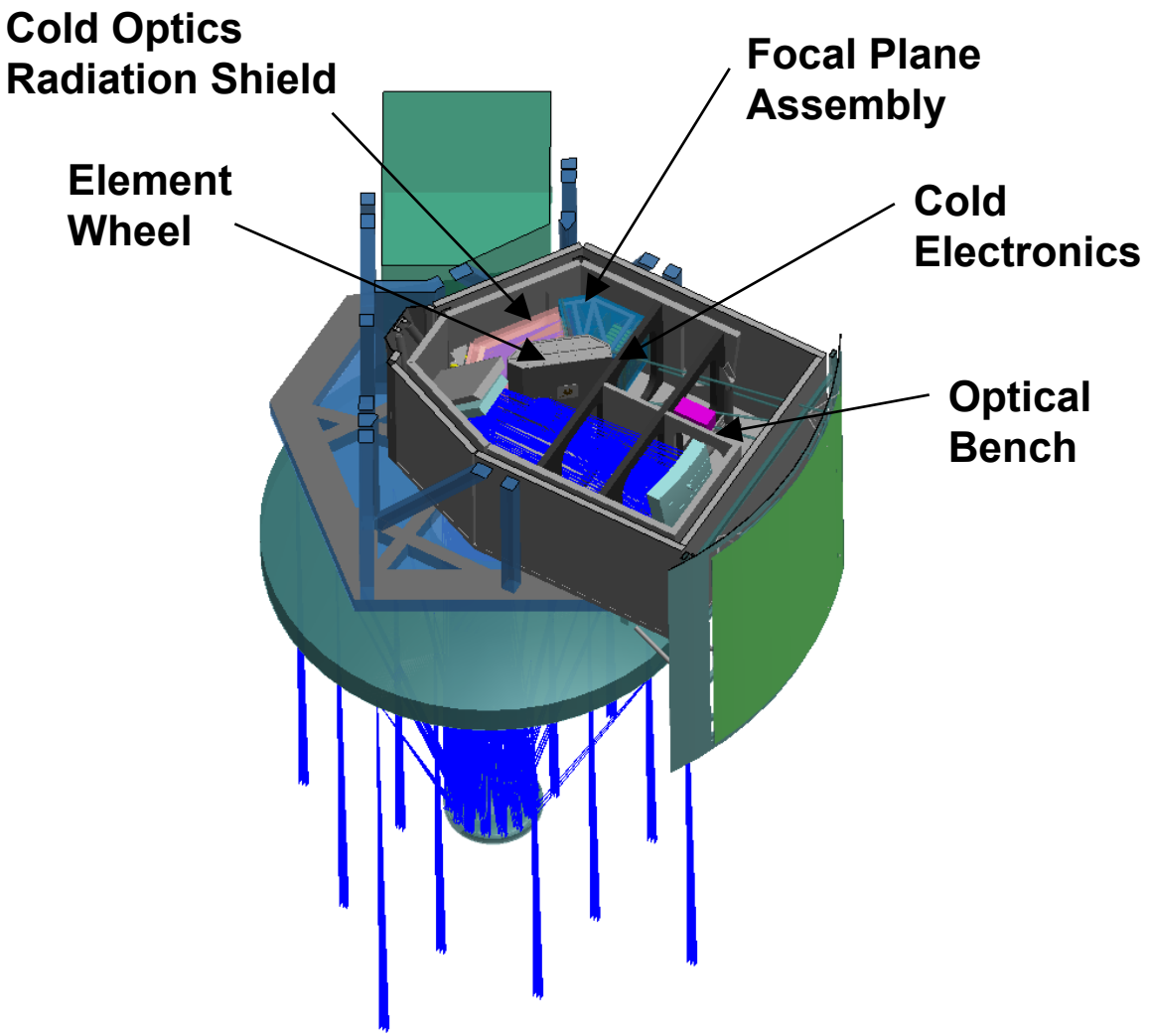
WF Instrument



Coronagraph

# Widefield Instrument Layout

- Single channel widefield instrument
- 3 mirrors, 1 powered
- 18 4K x 4K HgCdTe detectors
- 0.11 arc-sec plate scale
- IFU for SNe spectra, single HgCdTe detector
- Single filter wheel
- Grism used for GRS survey
- Thermal control – passive radiator



# WFIRST-AFTA Payload Block Diagram

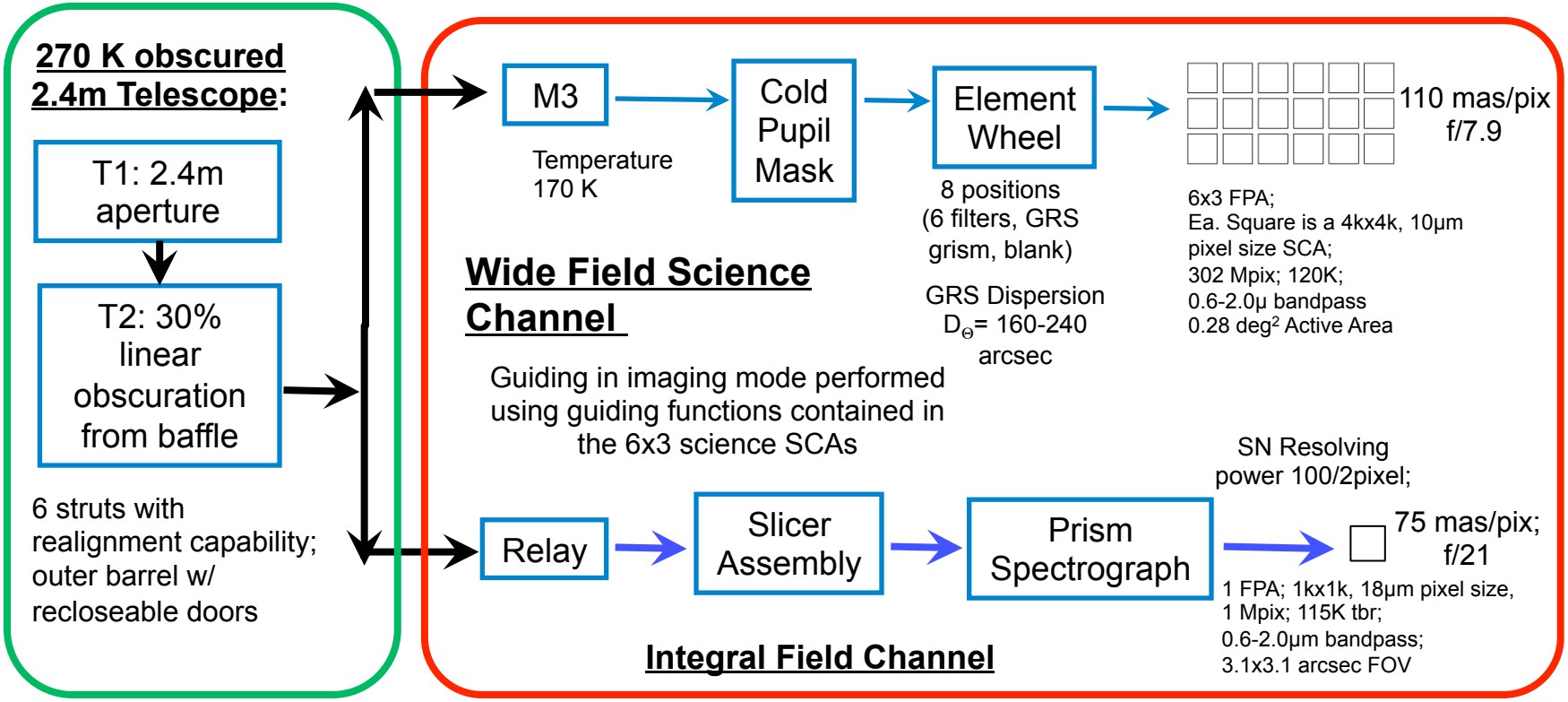
## Telescope

**270 K obscured 2.4m Telescope:**

- T1: 2.4m aperture
- T2: 30% linear obscuration from baffle

6 struts with realignment capability; outer barrel w/ recloseable doors

## Wide Field Instrument




GRS = Galaxy Redshift Survey
SCA = Sensor Chip Assembly
SN = Type1a Supernovae

2 fold mirrors in WF channel and 3 TBR in IFC not shown

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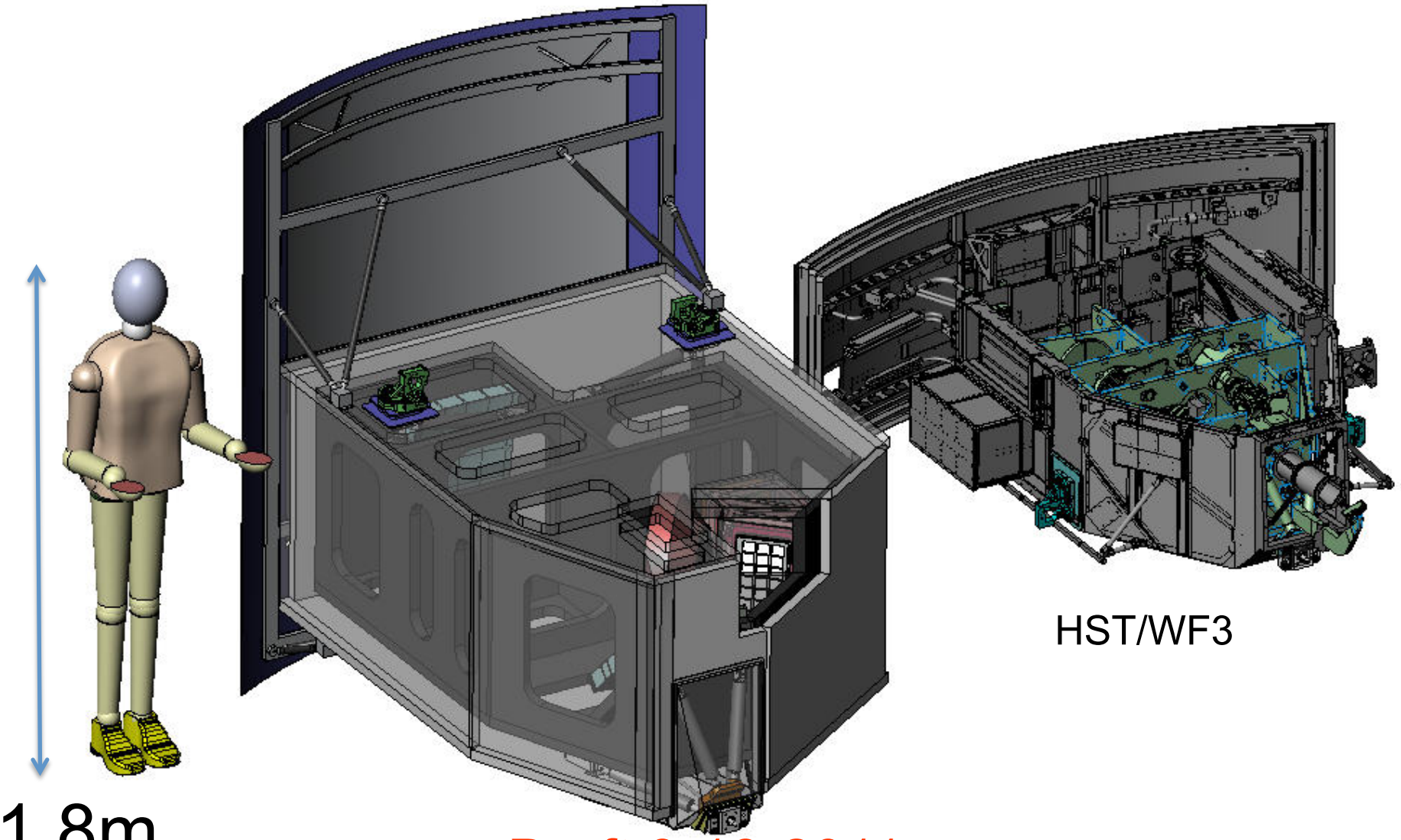
# Widefield Instrument Shares Architecture and Heritage with HST/WF3

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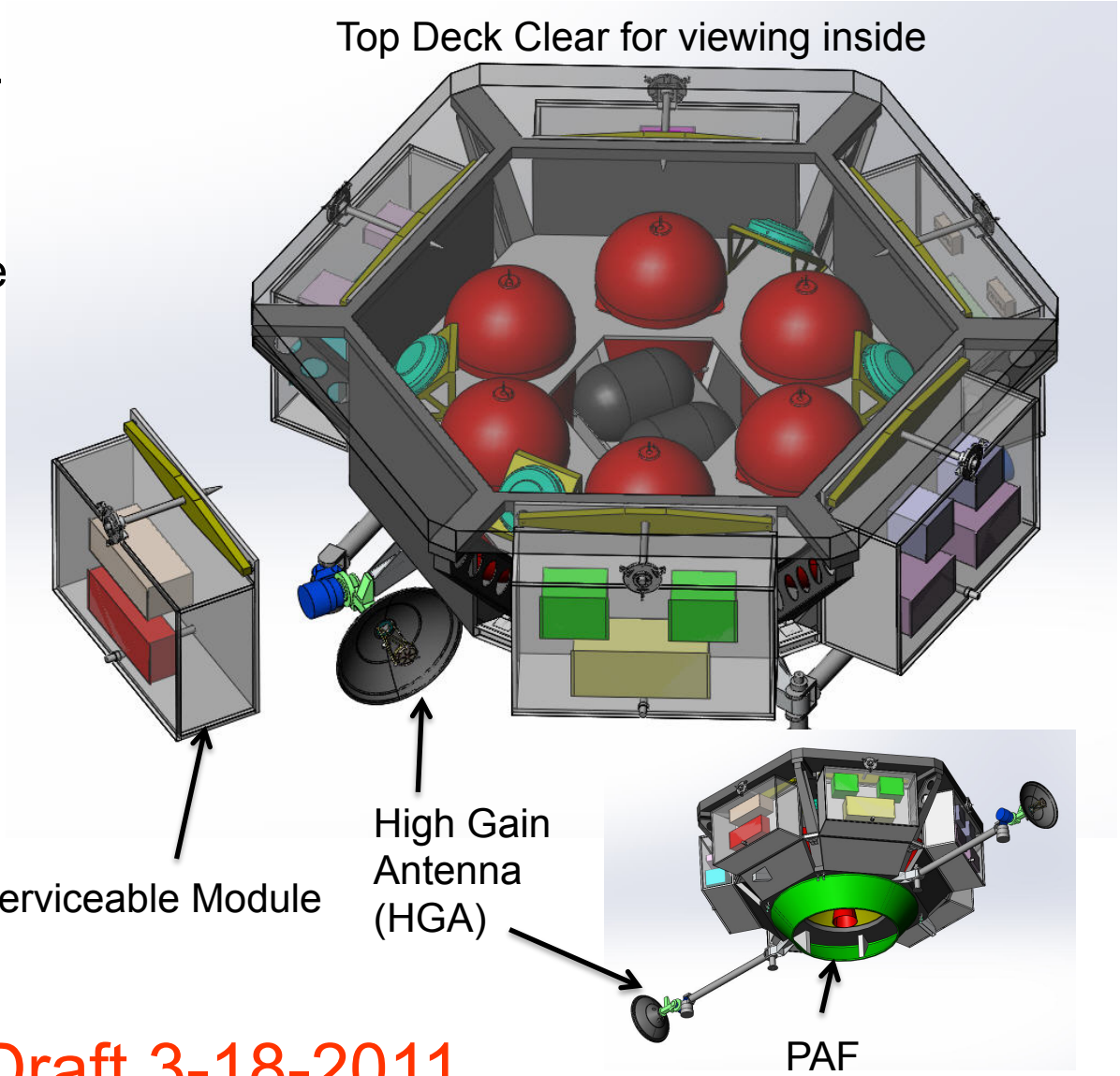
# Spacecraft Concept

- Spacecraft bus design relies on recent GSFC in-house spacecraft designs, primarily SDO and GPM
- 6 serviceable/removeable modules
  - Power
  - Comm
  - C&DH
  - ACS
  - Tele
  - Wide Field Elec
- Latch design reused from MMS
- 2 deployable/restowable HGAs
- Atlas 531 Payload Attach Fitting (PAF)
- 6 propellant tanks

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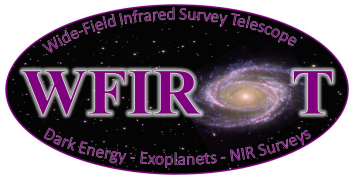



# Cost & Schedule

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# Cost Assumptions

- Life-cycle cost developed assumes the use of an existing 2.4m aperture telescope “as-is”.
- Six and one-half year development phase is assumed. Details in next chart.
- Five year operational phase baselined in cost.
- Cost developed using a combination of grassroots and parametric modeling, along with historical analogous GSFC missions.
- Life-cycle costs are presented for two schedule scenarios
  - The first assumes WFIRST-AFTA is developed along an optimal funding timeline, unconstrained by budget guidelines, resulting in the lowest baseline cost to compare against previous DRM estimates. This baseline is also used to later develop the cost for other what-if funding scenarios.
  - The second schedule scenario assumes pre-phase A studies continue through FY16, with Phase A beginning in FY17.
- Costs are presented in fixed year dollars (FY13) and real year dollars, with an estimate of the total number of equivalent work years.
- Option costs developed for the coronagraph, the cost of implementing serviceability, and the cost of optical communications.

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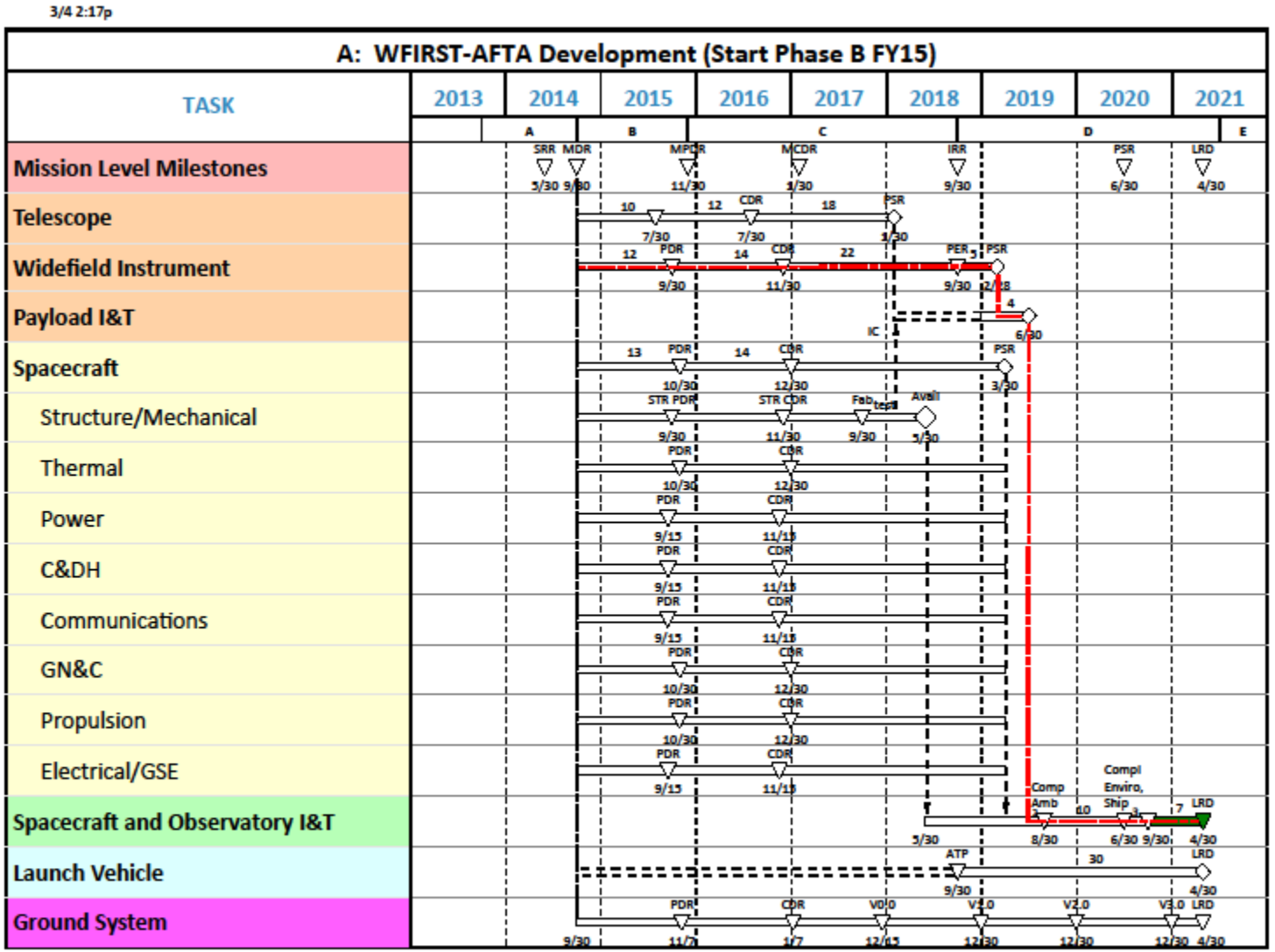
# WFIRST-AFTA Development Schedule

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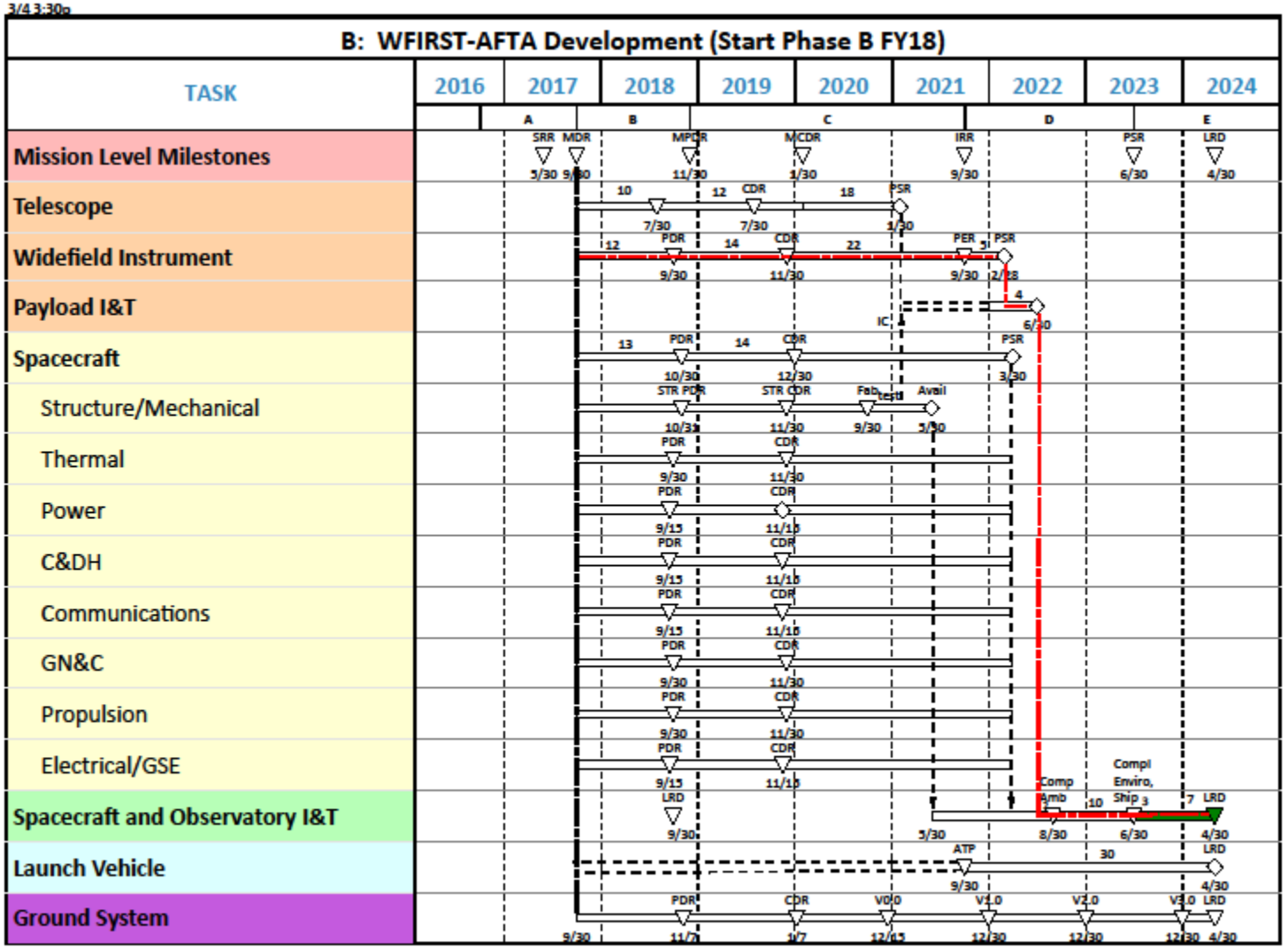
# WFIRST-AFTA Development Schedule

## (Start Phase B FY18)

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# WFIRST-AFTA Life Cycle Cost

## Unconstrained Budget Scenario – FY15 Start of Phase B

- LRD in 2021 followed by 5 year operational phase.
- Includes 7 months of funded schedule reserve.
- Includes 30% reserve on development phase and 5% reserve for operations phase.

| | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FY13 Dollars | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Real Years Dollars | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| FTEs | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z |

## Delayed Start Budget Scenario – FY18 Start of Phase B

- LRD in 2024 followed by 5 year operational phase.
- Includes 7 months of funded schedule reserve.
- Includes 30% reserve on development and 5% reserve for operations phase.

| | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FY13 Dollars | X | X | X | X | X | X | X | X | X | X | X | X | X |
| Real Years Dollars | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| FTEs | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z | Z |

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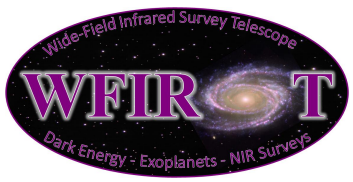


# Study Options


- Coronagraph
- Cost of Serviceability
- Optical Communications Option

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# WFIRST-AFTA Coronagraph Objectives

- Science:
  - Jeremy to provide input …
    - Direct Imaging and Spectrometry of Giant Planet
    - Dust
    - Polarimetry



- Starlight Suppression Technology Demonstration for flagship mission in the next decade.
  - Provides a unique opportunity to mature critical technologies in wavefront sensing & control and image calibration for improved contrast
  - Directly addresses the No. 1 ASTRO2010 recommendation for Medium-scale mission to develop Direct Imaging technologies.

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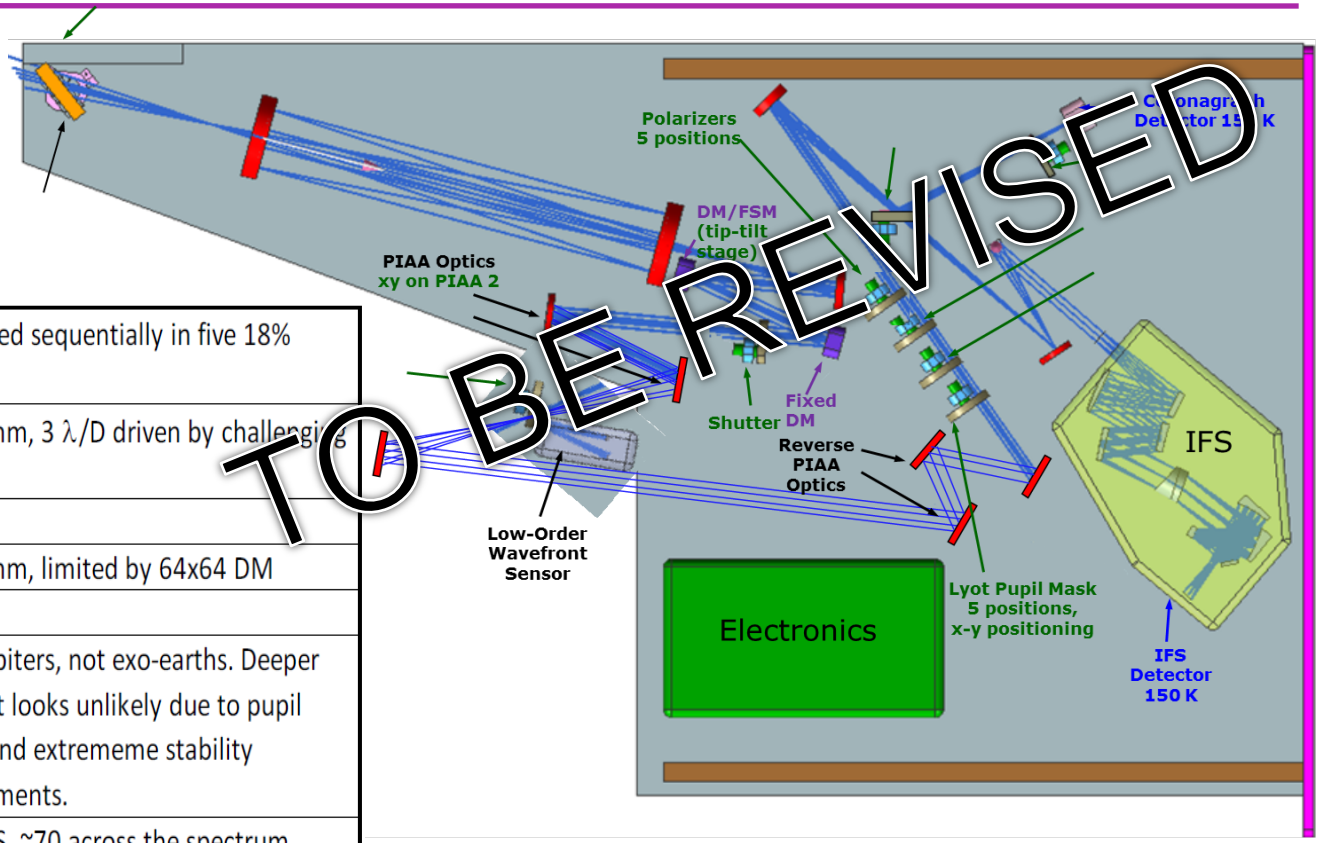
# WFIRST-AFTA Coronagraph Concept

| | | |
|---|---|---|
| Bandpass | 400-1000 nm | Measured sequentially in five 18% bands |
| Inner Working Angle | 100 mas | at 400 nm, 3 λ/D driven by challenging pupil |
| | 250 mas | at 1 um |
| Outer Working Angle | 1 arcsec | at 400 nm, limited by 64x64 DM |
| | 2.5 arcsec | at 1 um |
| Detection Limit | Contrast =$10^{-9}$ | Cold Jupiters, not exo-earths. Deeper contrast looks unlikely due to pupil shape and extrememe stability requirements. |
| Spectral Resolution | 70 | With IFS, ~70 across the spectrum. |
| IFS Spatial Sampling | 17 mas | This is Nyquist for λ400 nm. |




**WFIRST-AFTA baseline design with high throughput coronagraph (PIAA or Lyot) for starlight suppression including polarizers**

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# Observatory Requirements to Accommodate the Coronagraph

- Accommodations readily within WFIRST-AFTA baseline capabilities:
  - 80W power (CBE)
  - View to space for radiators
  - 29 Gbits/day (CBE)
  - Standard 1553 and SpaceWire interfaces

- The following requirements will be assessed during follow-on study analyses.
  - Linear thermal drift pointing stability: 10 mas (1 sigma)
  - Telescope thermal stability: mK–level
  - Dimensional stability (0.5 μm) between telescope and coronagraph
  - Impact of antenna articulation during coronagraph observing.

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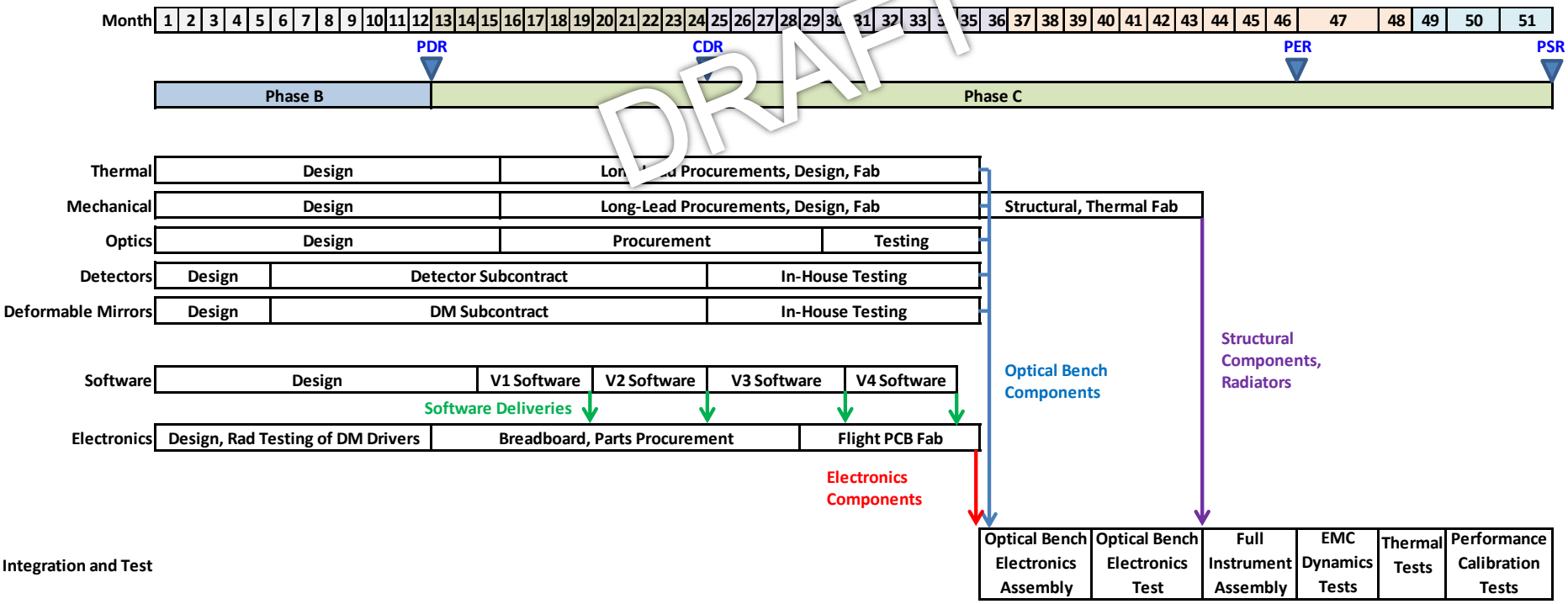
# Coronagraph Cost & Schedule

- Model-based cost estimates

| Cost Model | Estimated Cost |
|---|---|
| NICM System | $XM |
| NICM Subsystem | $XM |
| Price H | $XM |
| SEER | $XM |

- Schedule

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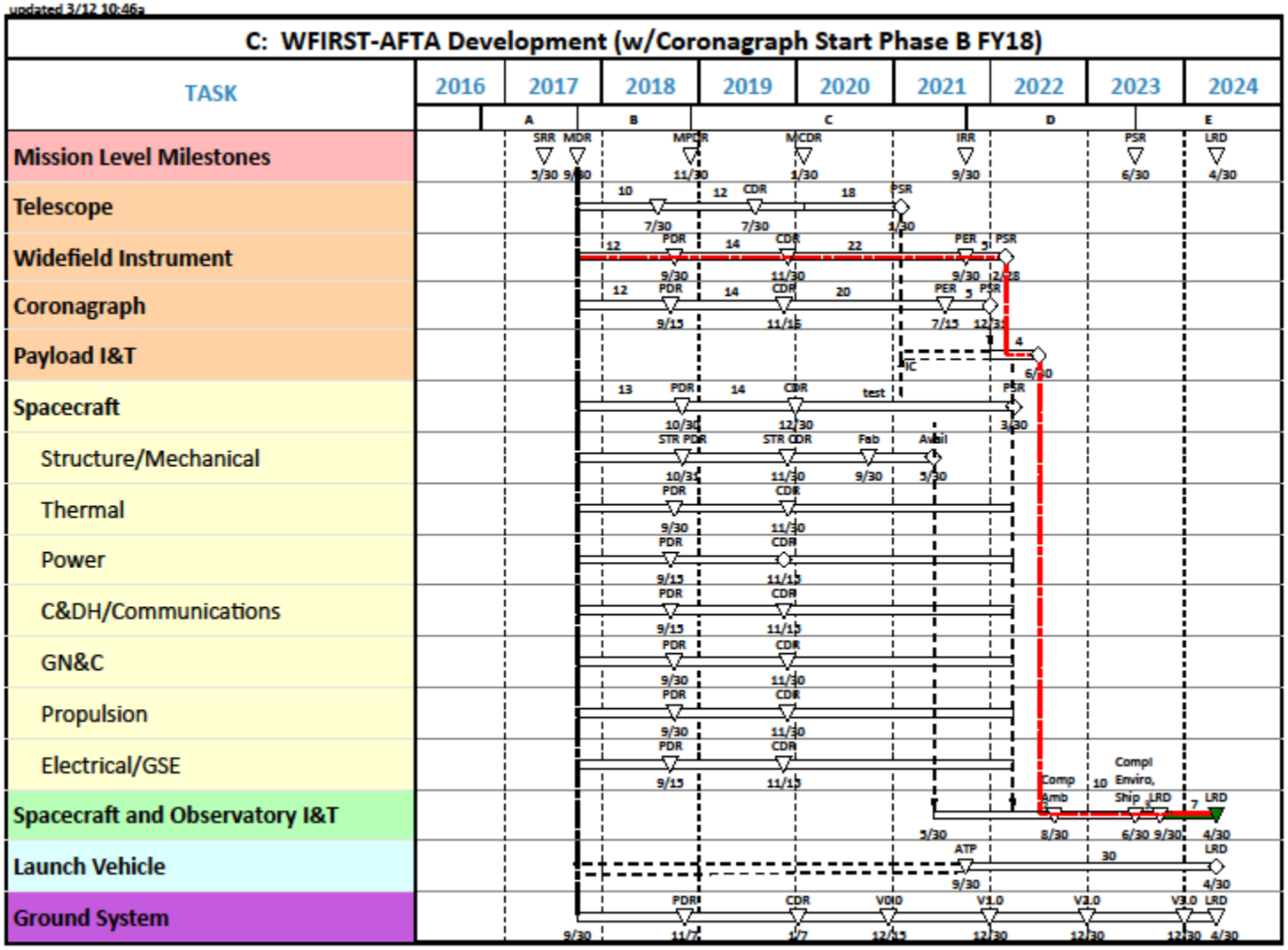
# WFIRST-AFTA Development Schedule

## (w/Coronagraph Start Phase B FY18)

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# Cost of Serviceability

- The WIRST-AFTA DRM arranges spacecraft and instrument hardware in robotically removable modules.
- In a conventional non-serviceable spacecraft, components are typically mounted on secondary structure, commonly panels.
- The change for WFIRST-AFTA is to make those panels readily removable. The spacecraft reference concept utilizes the attachment approach developed in the 1970's for the Multi-Mission Modular Spacecraft (MMS), and the instrument utilizes the mounting approach developed for HST in the 1980's.
  - Thus both approaches are low risk and TRL-9.
- Spacecraft integration will proceed exactly as it would for a traditional "non-serviceable" spacecraft.
  - No unique GSE requirements.
- The estimate of the additional design and hardware costs to incorporate serviceability into WFIRST-AFTA is XXM.
- The cost of a servicing mission or the infrastructure to execute a servicing mission is not included in this LCC.

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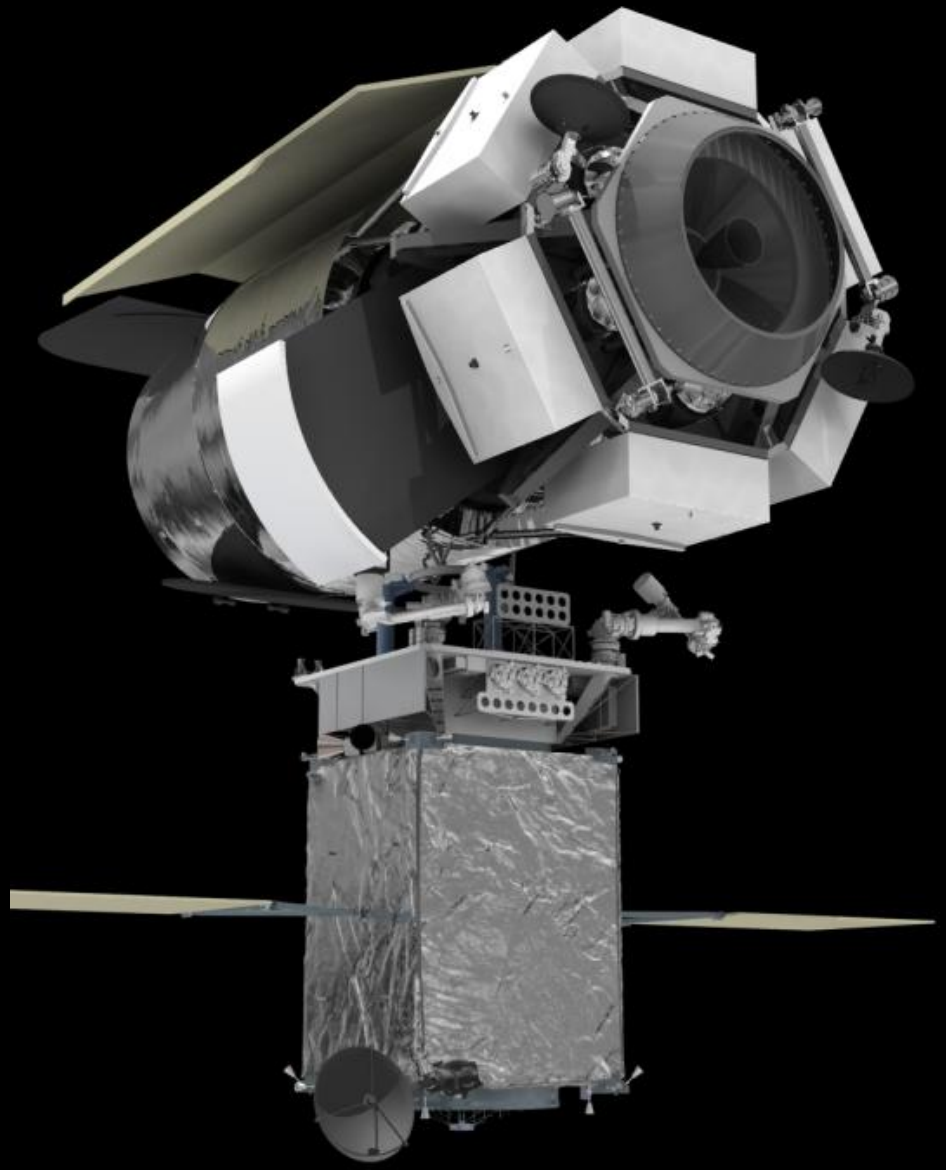
# WFIRST-AFTA with Servicing Vehicle



# Optical Communications Option

- Configuration –

- Cost of flight and ground elements –

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# Topics for Investigation in Follow-on Study

- Assess 2.5 micron wavelength cutoff for widefield instrument.
- Investigate options for radiator shielding to improve thermal performance.
- Further assess design limitations of telescope thermal design; analyses and coupon testing.
- Investigate options for internal instrument calibration.
- Initiate structural/optical/thermal analysis of the observatory.
- Optimize and refine widefield instrument design.
- Optimize and refine spacecraft packaging.
- Continue assessment of coronagraph options for WFIRST-AFTA.
- Optimize and refine science data downlink strategy, compression and SUTR.
- Continue to assess launch vehicle and transfer orbit options to optimize performance and minimize cost.

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# Summary

- Conclusion
  - The study of exoplanets and cosmic acceleration can be performed exquisitely with the combination of large aperture, fine sampling and widefield coverage.
  - The WFIRST-AFTA DRM can satisfy all of the observational requirements of Astro2010, while also enabling an extraordinary opportunity of additional astronomical investigations.
- The WFIRST technology is mature, and now the telescope is available.
- The time is right to initiate the WFIRST mission with the existing 2.4m aperture telescope.
  - The 2.4m telescope affords a unique opportunity to be responsive to Astro 2010 along with huge additional discovery possibilities.
- The SDT & Project's report will be completed on April 30, 2013.

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